introduced fishes

feature

Nonnative lake trout result in Yellowstone cutthroat trout decline and impacts to bears and anglers

ABSTRACT

During the past decade, Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) of Yellowstone Lake and its tributary streams have been affected by the introduction of lake trout (*Salvelinus naymaycush*), invasion by *Myxobolus cerebralis* (the cause of whirling disease), and drought conditions. Numbers of upstream migrating cutthroat trout at Clear and Bridge creeks have declined >90% in the past 5 years. Activity by bears has declined at spawning streams 1989–2004, and mirrored that of the cutthroat trout reductions, indicating cascading interactions in the food web of this system. Success by anglers has also declined, from two fish caught per hour in 1998 to less than one fish/h in 2004. To suppress lake trout, the National Park Service initiated a gillnetting program using up to 16 km of net each day, May–October. From 1994–2004, >100,000 lake trout were removed. The catch per unit effort and average length of spawning lake trout have declined, indicating that netting efforts may be impacting the population. As several important consumer species, including the threatened grizzly bear (*Ursus arctos horribilis*), use this population as an energy source, preservation of remaining cutthroat trout could be essential to maintain the integrity of the Greater Yellowstone Ecosystem.

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Introduction

The largest inland cutthroat trout population in the world is the adfluvial Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) population of Yellowstone Lake. These fish have great ecological (Schullery and Varley 1995), economic (Gresswell and Liss 1995), and historical significance, and they were noted by early explorers of the lake area for their beauty and abundance (Doane 1871). Shortly after the establishment of Yellowstone National Park as the world's first national park in 1872, the fishery was widely publicized in national and local newspapers, as well as periodicals such as *Forest and Stream* and *American Angler*. Anglers began visiting the lake, its tributary streams, and the Yellowstone River in great numbers, and the U. S. Fish Commission began looking for ways to propagate and distribute the cutthroat trout of Yellowstone Lake to locations across North America (Varley and Schullery 1998). The result was the development of a federally-operated fish culture facility on the north shore of Yellowstone Lake. From 1900 to 1956, over 818 million cutthroat trout eggs were removed for use in other waters, mostly outside Yellowstone National Park (Varley 1981; Varley and Gresswell 1988). The cutthroat trout also were subject to a great amount of angling pressure, and were commercially fished to provide food for visitors until 1919, just after the creation of the National Park Service (NPS). Evidence of a cutthroat trout population decline during the mid-1900s resulted in the closure of the egg-taking operations and implementation of increasingly restrictive angling regulations (Varley 1983; Gresswell and Varley 1988).

YELLOWSTONE NATIONAL PARK ARCHIVES

In the early and mid-1900s, tremendous numbers of cutthroat trout were harvested by sport anglers and commercial fishermen from Yellowstone Lake.

In streams throughout Yellowstone National Park and elsewhere in the natural range of Yellowstone cutthroat trout, populations have been compromised by introgression with nonnative rainbow trout (*O. mykiss*) or other cutthroat trout subspecies (Behnke 2002; Koel et al. 2004). The cutthroat trout of Yellowstone Lake and its tributaries have remained genetically pure due to isolation provided by the Lower and Upper falls of the Yellowstone River located 25 km downstream from the lake outlet near Canyon (Figure 1). The genetic purity of these fish makes them extremely valuable. However, the population has recently been exposed to three other potential stressors, including nonnative lake trout (*Salvelinus namaycush*; Kaeding et al. 1996), the exotic parasite *Myxobolus cerebralis* (the cause of whirling disease; Koel et al., in press), and a drought that has persisted throughout the Intermountain West, 1998–2004 (Cook et al. 2004).

Yellowstone Lake and its drainages provide a great variety of environmental conditions for the native cutthroat trout. At 34,000 ha, Yellowstone Lake is the largest lake above 2,000 m elevation in North America. Of the 124 tributaries flowing in to the lake, 68 have been used by spawning cutthroat trout (Jones et al. 1987; Gresswell et al. 1997). Geothermal features occur throughout much of Yellowstone Lake (Morgan et al. 2003), but unfortunately, it is the presence of these many unique and variable environments that may increase the vulnerability of this system to invasion by nonnative and exotic species such as lake trout, *M. cerebralis*, and possibly others in the future. Prior to Euroamerican manipulation, the Yellowstone Lake cutthroat trout existed for approximately 10,000 years (since glacial recession) in sympatry with only one other fish species, the longnose dace (*Rhinichthys cataractae;* Behnke 2002). Now, longnose suckers (*Catostomus catostomus*), lake chubs (*Couesius plumbeus*), redside shiners (*Richardsonius balteatus*), and lake trout are also present in the lake system due to introductions.

Contemporary research points to nonnative species as the greatest threat to cutthroat trout of the Intermountain West (Gresswell 1995; Kruse et al. 2000; Dunham et al. 2004). With the recent invasions by lake trout and *M. cerebralis*, the park is placing a high priority on preservation and recovery of the cutthroat trout. This subspecies is important for maintaining the integrity of the Greater Yellowstone Ecosystem, arguably the most intact naturally-functioning ecosystem remaining in the lower 48 United States. Grizzly bear (*Ursus arctos horribilis*), bald eagle (*Haleaeetus leucocephalus*), and many other avian and terrestrial species use cutthroat trout as an energy source (Swenson et al. 1986; Gunther 1995; Schullery and Varley 1995).

Nonnative lake trout would not be a suitable ecological substitute for cutthroat trout in the Yellowstone Lake system because they are inaccessible to most consumer species. Lake trout tend to occupy greater depths within the lake than do cutthroat trout. Lake trout remain within Yellowstone Lake at all life stages and they do not typically enter tributary streams, as do cutthroat trout. Evidence from other, similar systems, suggests that introduced lake trout will result in the decline of cutthroat trout (Cordone and Franz 1966; Dean and Varley 1974; Behnke 1992). Bioenergetics modeling suggests that an average-sized mature lake trout in Yellowstone Lake will

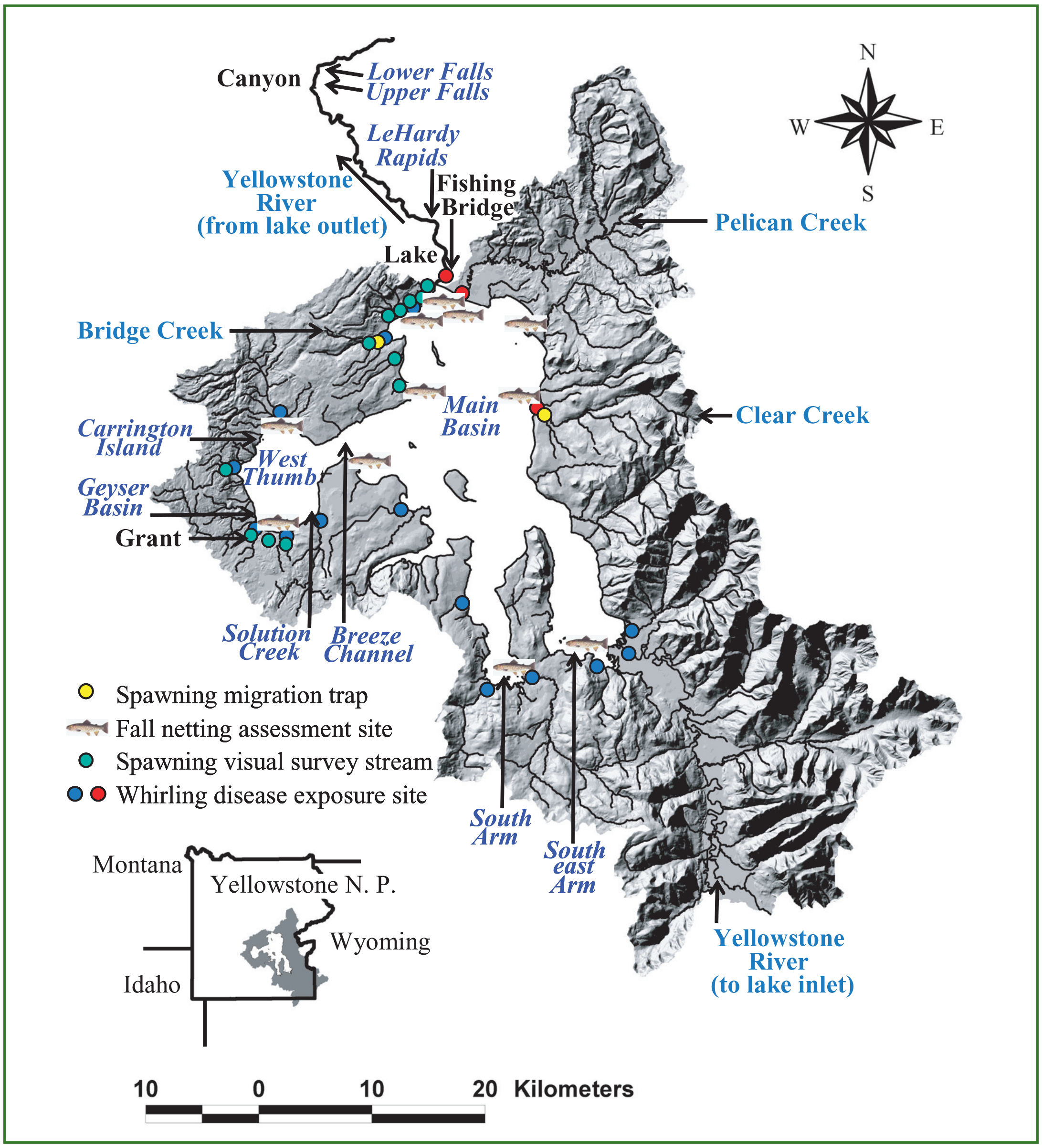


Figure 1. Yellowstone Lake and tributary drainages within Yellowstone National Park, with locations of cutthroat trout spawning migration traps, cutthroat trout fall netting assessment sites, cutthroat trout spawning visual survey streams, and whirling disease sentinel fry exposure sites (blue = negative and red = positive for the presence of *Myxobolus cerebralis*).

An aggressive gillnetting program targets spawning lake trout on Yellowstone Lake during September each year.

consume 41 cutthroat trout per year (Ruzycki et al. 2003). Following the guidance of a lake trout expert advisory panel (McIntyre 1995), the NPS has used gillnetting to determine the spatial and temporal distribution of lake trout within Yellowstone Lake. The efforts have led to a long-term lake trout removal program for the protection of the cutthroat trout in this system (Mahony and Ruzycki 1997; Bigelow et al. 2003).

The overall purpose of this paper is to describe the current status of NPS efforts to preserve the integrity of the Yellowstone Lake ecosystem. Specifically, our objectives are to (1) describe trends in cutthroat trout abundance and size, (2) examine the impacts on bears and anglers, and (3) describe results of efforts to suppress lake trout population growth.

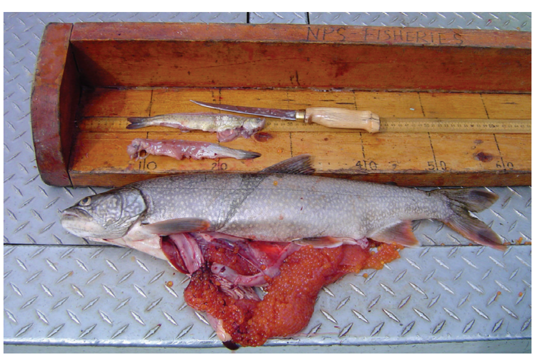
Methods

Cutthroat trout spawning migration traps. The NPS has monitored the cutthroat trout spawning population by counting upstream-migrating adults at Clear Creek and Bridge Creek since 1945 and 1999, respectively (Figure 1). From May–July each year, the cutthroat trout are counted at permanent weirs as they move upstream from Yellowstone Lake to spawn. Until 1998, all fish were trapped and manually enumerated. Since then, electronic counters have been used (Pulsar Electronics, LTD., North Vancouver, British Columbia, Model 550BB).

Cutthroat trout fall netting assessment. Within Yellowstone Lake, cutthroat trout population abundance and length structure have been assessed by netting conducted during September of each year since 1969. Multi-mesh-size (experimental) gillnets (38.0 m length, 7.6 m graduated mesh panels of 19, 25, 32, 38, and 51 mm) are placed in sets of five nets perpendicular to the shoreline overnight, in shallow water (0–5 m depth), at 11 sites throughout Yellowstone Lake (Jones et al. 1977; Figure 1).

Cutthroat trout spawning visual surveys. Visual surveys for cutthroat trout and bear activity have been conducted annually since 1989 on 9–11 tributaries located along the western side of Yellowstone Lake between Lake and Grant (Reinhart 1990; Reinhart et al. 1995; Figure 1). Spawning reaches were initially delineated on each tributary, and the standardized reaches are walked in an upstream direction once each week from May through July. The observed cutthroat trout are counted, and the weekly activity by black bears (*U. americanus*) and grizzly bears is estimated by noting the presence of scat, parts of consumed trout, fresh tracks, and/or bear sightings.

Angler report card information. Since 1979, angler effort and success has been assessed via a report card distributed to all anglers upon purchasing a special use permit for fishing (Jones et al. 1980). Information on the waters fished, time spent, and species and sizes of fish caught by anglers is obtained. Annually, approximately 4,000 anglers (5% of all anglers) have voluntarily completed and returned cards to the park's fisheries program.



COLLIN CHRISTIANSEN

Bioenergetics research suggests that each lake trout in Yellowstone Lake has the potential to consume 41 cutthroat trout or more each year.

Lake trout removal program. Gillnetting has been used to suppress lake trout in Yellowstone Lake each year since 1994. Spatially, the gillnet locations have been concentrated in the West Thumb, where lake trout densities have been found to be highest (Figure 1). Through the years of the program, however, lake trout and gillnetting have expanded outward to include the main basin and, to a lesser extent, the southern arms. Small-mesh (19–44 mm mesh size) gillnets were placed on the lake bottom in water typically 40–65 m deep. Gillnets were 300 m length, set in gangs of six contiguous nets (1800 m total length each), typically for >7 days. During the open water season (late May-late October), up to 16 km of gillnet were in place fishing for lake trout.

The mature lake trout of Yellowstone Lake begin congregating near known spawning locations in late August each year. The removal program targets these fish until early October, when spawning is typically completed. The locations targeted in the fall, including Breeze Channel, Carrington Island, Geyser Basin, and Solution Creek (Figure 1), were gillnetted using shallow-set (0–20 m depth), large-mesh gillnet (51–70 mm mesh size) sets of short duration (typically one day) to reduce mortality of any cutthroat trout bycatch. In 2004, boat-mounted electrofishing was also used to remove spawning lake trout and kill deposited eggs in shallow waters (<5 m depth) at night.

Whirling disease prevalence and severity. The prevalence of *M. cerebralis* within Yellowstone Lake was determined by examination of juvenile and adult cutthroat trout mortalities from the fall netting assessment and lake trout removal program, 1998–2003. Screening of these fish occurred initially by the pepsin trypsin digest (PTD) method to examine for the presence of myxospores (Andree et al. 2002) followed by the nested polymerase chain reaction (PCR) technique to confirm the presence of *M. cerebralis* (Andree et al. 1998).

The prevalence and severity of *M. cerebralis* within 15 tributaries and the Yellowstone River (lake inlet and lake outlet) was determined by use of cutthroat trout sentinel fry exposures, 1998–2003 (Koel et al., in press). In each cage (1 m height 0.5 m diameter and constructed of 5 mm galvanized wire mesh), 60–80 cutthroat trout fry (25–50 days post hatch) were exposed for a 10-day period, July–September. Following the exposures, fry were held in aquaria for an additional 90 days at 10–13°C to allow parasite development prior to being sacrificed. The PCR technique (Andree et al. 1998) was used to test for the presence of *M. cerebralis*. Histological examination was conducted on fry from *M. cerebralis*-positive exposures to determine severity of infection. Severity was ranked on a scale of 0 (no infection) to 5 (most severe infection) for each fry examined (Baldwin et al. 2000).

Trends in Cutthroat Trout Abundance

Impacts of historical egg-taking operations and liberal angler harvest regulations for Yellowstone Lake cutthroat trout were observed in counts of upstream-migrating fish at Clear Creek. Only 3,161 cutthroat trout ascended

Clear Creek in 1954, just two years prior to the cessation of fish culture operations on Yellowstone Lake (Varley and Schullery 1998; Figure 2). With angling restrictions, the number rebounded during the 1960s and 1970s to 70,105 cutthroat trout in 1978 (Jones et al. 1979). Although there was variation among years, the increasing trend in cutthroat trout abundance within Yellowstone Lake was also indicated by the fall netting assessment. An average of 10.0 fish per net were caught by this assessment in 1969, and 19.1 fish per net were caught in 1984 (Figure 2).

Since the late 1980s, however, there has been a significant decline in the Yellowstone Lake cutthroat trout population. The number of upstream-migrating cutthroat trout counted at Clear Creek was 1,438 during 2004 (Figure 2). This count was down from 3,432 in 2003, and 6,613 in 2002, and was the lowest count since 1954. The fish counting station operated on Bridge Creek, a small northwestern tributary, indicated that only a single fish migrated upstream during 2004 (Figure 2). The number of spawning cutthroat trout in recent years has declined by more than 50% annually in Bridge Creek, and has decreased by over 99% since counts began in 1999 (when 2,363 cutthroat trout ascended the stream to spawn). The decline was also evident in results of the fall netting assessment, where an average of 15.9 cutthroat trout per net were caught in 1994, and only 6.1 per net were caught in 2002 (Figure 2). Prior to 2003, the reduction in catch by the fall netting program averaged 11% per year since 1994, the year lake trout were first discovered in Yellowstone Lake. During 2003–2004, however, the fall netting assessment provided some of the first indications that the cutthroat trout population may be responding positively to efforts to remove nonnative lake trout. An average of 7.4 fish per net were caught in 2003, and 7.9 fish per net were caught in 2004.

Trends in Cutthroat Trout Length

Length-frequency data from the fall netting program from 1997 to 2004 indicated an increase in length (>325 mm) and reduction in numbers of adult cutthroat trout in Yellowstone Lake (Figure 3). In 2004, fewer

Figure 2. Number of upstream-migrating cutthroat trout counted at Clear Creek (1945–2004) and Bridge Creek (1999–2004) spawning migration traps (A), and mean number of cutthroat trout collected per net during the fall netting assessment on Yellowstone Lake, 1969–2004 (B). Note differences in scale between Clear Creek and Bridge Creek data.

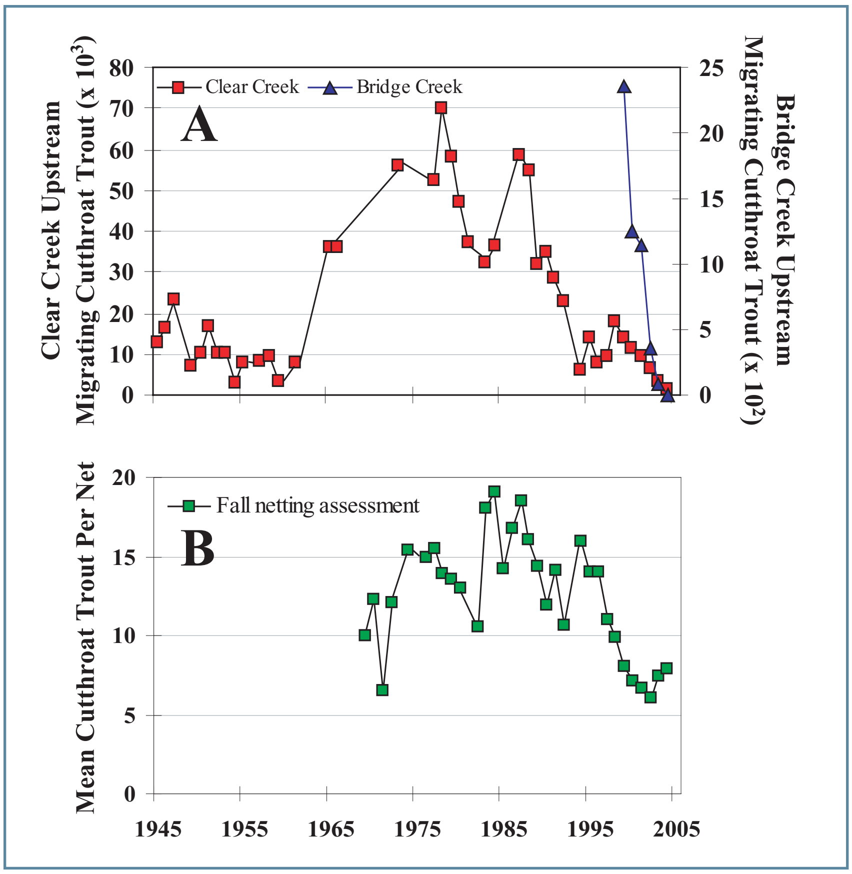
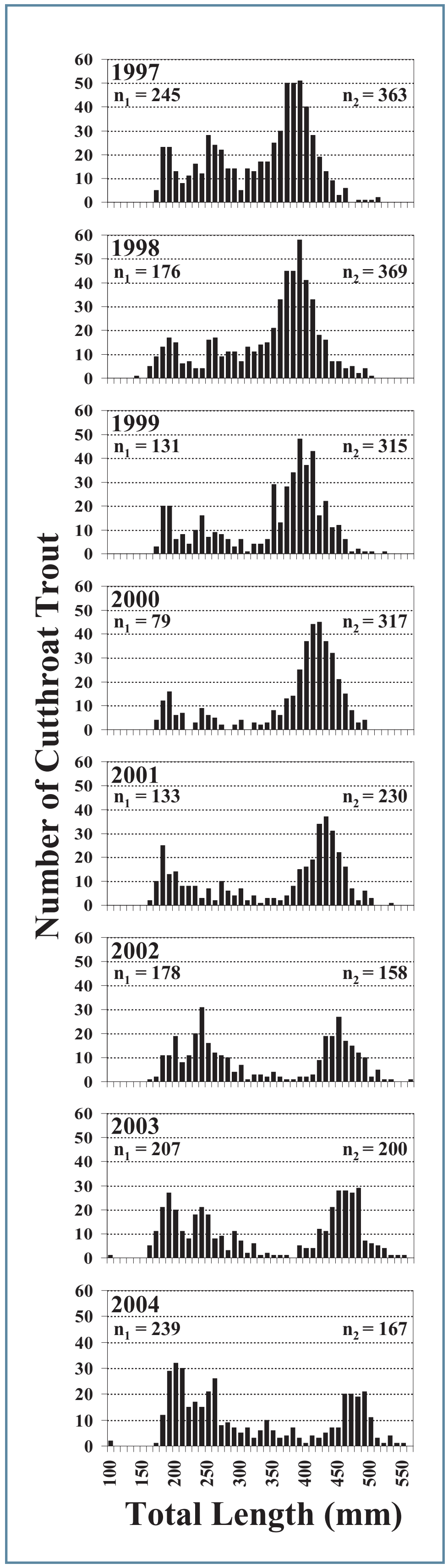


Figure 3. Length-frequency distributions of cutthroat trout collected during the fall netting assessment on Yellowstone Lake with total number of trout <325 mm (n_1) and >325 mm (n_2), 1997–2004.



fish between the lengths of 325 and 425 mm were collected compared to earlier years. Historically, most cutthroat trout sampled in spawning tributaries such as Clear Creek were in this size range (Jones et al. 1993). Despite this, an apparent increase in numbers of juvenile cutthroat trout (100–325 mm) has been noted in recent years (2002–2004). Many of these juveniles have been collected in the southern arms of Yellowstone Lake (Figure 1), which may act as refuges for cutthroat trout due to the low numbers of lake trout and low incidence of *M. cerebralis* in these areas (see below; Koel et al. 2004).

Influence on Cutthroat Trout Consumers

Upstream-migrating cutthroat trout within Yellowstone Lake tributaries historically have served as a significant source of energy for black bears and grizzly bears in the lake area (Reinhart and Mattson 1990). The average number of cutthroat trout observed each week during spawning visual surveys of 9–11 tributaries (1989–2004) has declined to the point where few trout have been observed in recent years (Figure 4). In fact, only 35 cutthroat trout were seen on spawning reaches of the 9 streams surveyed over a period of 8 weeks in 2004. A similar trend was observed in use of these streams by black bears and grizzly bears. It was apparent that few bears used these tributaries, as bear activity was only evident a total of 8 times during 2004. By comparison, the visual surveys of spawning cutthroat trout documented activities by bears 50 times in 1991. These results suggest a trophic-level cascade (Spencer et al. 1991), possibly resulting from the introduction of nonnative and exotic species into this pristine ecosystem (Reinhart et al. 2001). Bears may have been forced to use other energy sources in the region during the spring-spawning period when they previously relied on cutthroat trout.

Figure 4. Mean number of cutthroat trout and mean activity by black bears and grizzly bears observed during weekly spawning visual surveys of 9–11 tributaries located along the western side of Yellowstone Lake between Lake and Grant, 1989–2004.

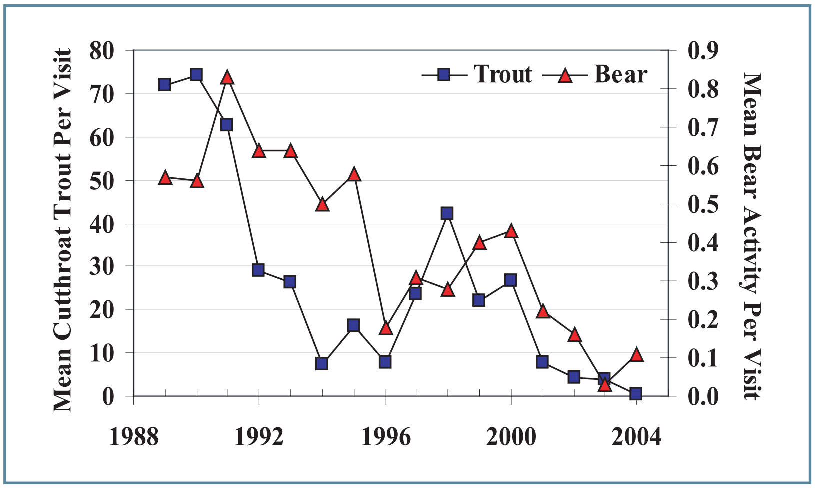
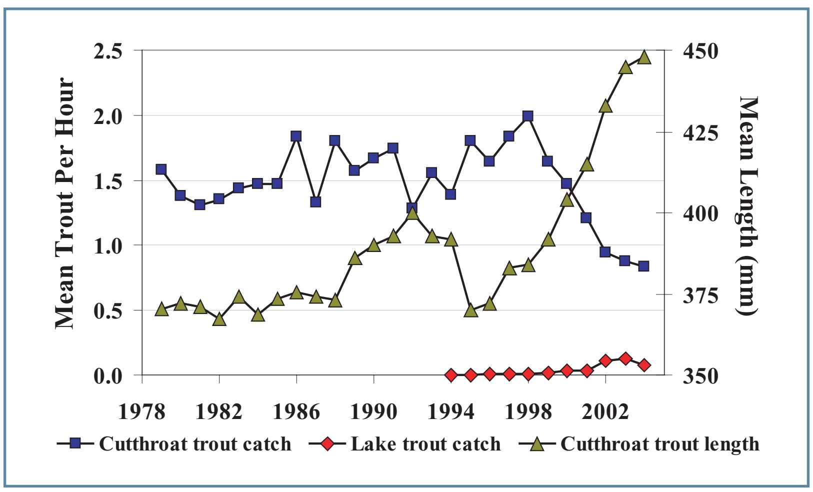


Figure 5. Angler-reported catch rate for cutthroat trout and lake trout, and the average length of cutthroat trout caught by anglers from Yellowstone Lake, 1979–2004.



Aside from localized displacement it is not known what the overall effect of cutthroat trout declines will be on bear populations, as bears of this region are also threatened by the decline of whitebark pine (*Pinus albicaulis*; Mattson and Merrill 2002). Despite this threat to important food sources, the status of the grizzly bear population in the Greater Yellowstone Ecosystem is currently considered to be stable to increasing. The grizzly bear population has increased from an estimated 136 bears in 1975 when it was listed as a threatened species, to at least 431 bears in 2004 (Haroldson and Frey in press). In addition, grizzly bears have expanded their range by 48% over the last two decades (Schwartz et al. 2002).

Yellowstone National Park has long been a destination for anglers from around the world. Historically, more than one-third of visiting anglers fished Yellowstone Lake. In recent years, estimates derived from returns of angler report cards suggest that anglers on Yellowstone Lake have experienced a decline in the number of cutthroat trout caught per hour from 2.0 in 1998 to 0.8 in 2004 (Figure 5), while lake trout caught per hour increased from 0.0 in 1998 to 0.1 in 2004. In addition, the average length of cutthroat trout caught by anglers on Yellowstone Lake has increased from 370 mm in 1995 to 448 mm in 2004. The decline in numbers of cutthroat trout caught by anglers has been even more significant on Pelican Creek (Figure 1), the lake tributary where *M. cerebralis* infection has been most severe (see below). The number of cutthroat trout caught per hour has declined from 2.5 in 1979 to 0.3 in 2003. Since 2001, regulations have required that cutthroat trout be immediately released unharmed. Angling on the Pelican Creek drainage was completely closed in 2004 in an attempt to slow the dispersal of *M. cerebralis* to other park waters.

Lake Trout Removal Program a Decade after Discovery

Since the discovery of lake trout in Yellowstone Lake in 1994 (Kaeding et al. 1996), efforts to counteract this nonnative species have intensified. The NPS gillnetting program has removed >100,000 lake trout since 1994 (Figure 6). The gillnetting effort has increased in recent years to an average of 10 times that of 1999. A total of 26,634 lake trout were removed in 2004 using 15,781 effort units (one effort unit = 100 m of net set over one night). Catch rate has declined since 1998, when an average of 5.5 lake trout per unit of effort were caught. In

2004, catch per unit effort (CPUE) for lake trout remained low (1.69) but was slightly higher than that of 2001–2003.

Avoiding bycatch of cutthroat trout has been a challenge for the lake trout removal program. Initially, the bycatch was very high: 6.6 cutthroat trout for every lake trout netted in 1995. This high bycatch was in part due to the higher densities of cutthroat trout and lower densities of lake trout that occurred within Yellowstone Lake during the mid-1990s. Gillnetting protocols have been improved to reduce bycatch while maximizing removal of lake trout. The gillnets are now consistently set very deep (40–65 m depth), except during lake trout spawning periods. The bycatch has been 0.1 cutthroat trout or less for each lake trout netted since 1998.

As the lake trout population has grown and expanded in recent years, spawning fish have become a focal point for the removal program. In 2003, an additional lake trout spawning location was identified near the West Thumb Geyser Basin (Figure 1). This area, along with areas near Carrington Island, Solution Creek, and Breeze Channel, has been gillnetted since 1996. The total number of spawning lake trout caught by gillnetting was 2,371 in 2003 and 7,283 in 2004 (Figure 6). An additional 1,063 spawning lake trout were removed by electrofishing in 2004. The average length of spawning lake trout removed near spawning areas has decreased each year (Figure 6). The recent decline in the annual lakewide catch rate of lake trout and the annual reduction in the average length of sexually mature fish are positive indications that the removal program is exerting measureable mortality on this population.

Lake trout densities in the West Thumb remain high and a serious threat to the cutthroat trout. Model simulations suggested a 60% or greater decline in the cutthroat trout population within 100 years if the lake trout population was permitted to grow uncontrolled (Stapp and Hayward 2002). Cutthroat trout abundance indices suggest that a decline of that magnitude (or greater) has already occurred. The NPS will continue to investigate new methods to target the lake trout population. In particular, using hydroacoustics, underwater cameras, and high resolution (1 m) bathymetry, NPS is currently delineating and characterizing known lake trout spawning areas (all presently in the West Thumb), to predict where new spawning areas may be pioneered in the lake basin. These potential spawning areas will be closely monitored and targeted for lake trout removal if fish begin to use them in the future.

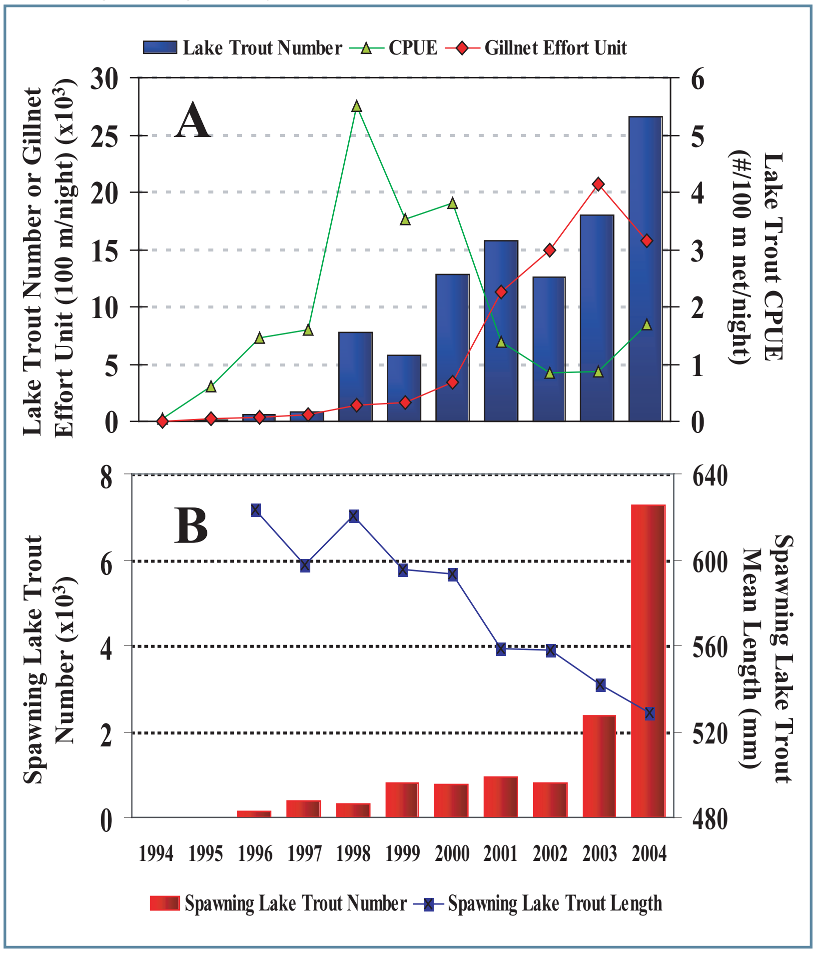
Whirling Disease and Drought as Additional Threats

Myxobolus cerebralis was discovered in Yellowstone Lake in 1998 among juvenile and adult cutthroat trout (Koel et al. in press). Examination of gillnetting mortalities has since confirmed the presence of the parasite throughout Yellowstone Lake, with highest prevalence existing in the northern region of the lake, near known infected streams (see below; Koel et al. 2004). Although the widespread presence of this harmful parasite in the lake is disturbing, the discovery of *M. cerebralis* spores in adult fish each year suggests that at least some cutthroat trout are surviving initial *M. cerebralis* infection.

By 2001, cutthroat trout sentinel fry exposures confirmed the presence of *M. cerebralis* in three important spawning streams: Pelican Creek, Clear Creek, and the Yellowstone River downstream from the lake outlet near Fishing Bridge (Figure 1; Koel et al. in press). Since then, sentinel exposures in the Yellowstone River upstream of the lake inlet and 13 other spawning tributaries have failed to detect the presence the parasite. The impacts of *M. cerebralis* have been most severe in Pelican Creek, where few wild-reared fry have been observed in recent years (2001–2004). Cutthroat trout sentinel fry exposures in this tributary have indicated that >90% of the fry were infected with *M. cerebralis*, with an average severity (by histological examination) of >4 on a scale of 0 (no infection) to 5 (most severe infection; Koel et al. 2004).

Consistent, annual counts of upstream-migrating adult cutthroat trout have not been made in Pelican Creek in recent years, but records exist from a historic weir that was previously used to enumerate spawning fish from 1964 through 1981 (Jones et al. 1982). Netting near the location of the historic weir (near the tributary mouth) for upstream-migrating adults in 2002–2004 indi-

Figure 6. Number of lake trout removed, gillnet units of effort (1 unit = 100 m of net/night) used, and lake trout catch per unit of effort obtained by the lake trout removal program on Yellowstone Lake during the entire gillnetting season, 1994–2004 (A). Number and mean length of mature lake trout removed near spawning locations (Breeze Channel, Carrington Island, Geyser Basin, and Solution Creek) on Yellowstone Lake during late August–early October, 1996–2004 (B).



cated that the spawning cutthroat trout population of Pelican Creek, which in 1981 was nearly 30,000 fish, has been essentially lost. With a drainage area of 17,565 ha, Pelican Creek is the second largest tributary to Yellowstone Lake in terms of discharge.

Drought in the Intermountain West since 1998 may have impacted cutthroat trout populations due to increased water temperatures and a reduction in peak stream flows (U.S. Geological Survey unpublished data for gage 06186500 Yellowstone River at Yellowstone Lake Outlet). In many cases, flows in tributary streams have become sub-terminal near the lake, flowing through large sand and gravel bars. This disconnect of tributary streams from the lake has been occurring during mid-summer and fall, when cutthroat trout fry would typically be outmigrating to Yellowstone Lake. Biologists have consistently noted cutthroat trout fry that are stranded in isolated side channels and pools in seasonally-disconnected tributaries. Although cutthroat trout have existed in the Yellowstone Lake ecosystem since glacial recession (Behnke 2002), and evolved in the face of great variation in thermal and other environmental regimes, the current drought is occurring during a period when the cutthroat trout are also impacted by lake trout predation and *M. cerebralis*.

Conclusions

Our results identify long-term impacts of lake trout and *M. cerebralis* on cutthroat trout in Yellowstone Lake and the Greater Yellowstone Ecosystem. Even with the Yellowstone National Park fisheries program dedicated to the preservation and recovery of the Yellowstone Lake cutthroat trout population, it appears to be in peril. In addition, two important cutthroat trout consumers, the black bear and grizzly bear (icons for Yellowstone National Park and highly sought by millions of visitors each year), are using cutthroat trout spawning streams much less frequently. Yellowstone National Park anglers, a third of which fish Yellowstone Lake, also have experienced a significant reduction in catch.

Of great interest to park managers is the timing and original source of lake trout that were illegally introduced to Yellowstone Lake. Research on the microchemistry (Sr:Ca ratios) of otoliths has suggested that a lake trout introduction likely occurred in the late 1980s (Munro et al. 2005). These results suggest that lake trout existed in Yellowstone Lake for at least five years prior to being reported to the NPS by an angler. The otolith microchemistry, as well as comparative DNA analyses, has provided evidence that the lake trout origin was Lewis Lake (Stott 2004; Munro et al. 2005), a lake within the park that was intentionally stocked with lake trout from Lake Michigan in 1890 (Varley 1981). To date, it remains unknown exactly how the lake trout were introduced to Yellowstone Lake.

At present, a mandatory kill regulation is in place for all lake trout caught on Yellowstone Lake, and the NPS asks anglers each year to assist with the lake trout removal effort in this way. The Yellowstone Lake situation represents a unique case in which anglers are solicited to fish for lake trout without the desire to preserve the fishery. In NPS requests for angler support, it is made clear that the goal is removal of as many lake trout as possible and suppression of the population for the purpose of cutthroat trout conservation. To this point a constituency has not developed requesting the enhancement of the lake trout fishery in Yellowstone Lake.

Since lake trout in Yellowstone Lake are known to prey on the native cutthroat trout (Ruzycki et al. 2003), the removal of >100,000 lake trout has reduced predation on this important population. The lake trout removal program on Yellowstone Lake represents a test case for the development of similar programs to preserve native salmonids in the Intermountain West. For example, lake trout removal is currently being experimentally conducted on Lake Pend Oreille in northern Idaho, and is being considered for Lake McDonald of Glacier National Park and Swan Lake of northwestern Montana.

The cumulative effects of lake trout and *M. cerebralis* have put stress on the Yellowstone Lake cutthroat trout population during a period of intense drought in the Intermountain West. The cutthroat trout population size of this system was once considered to be in the millions: however, current abundance indices suggest that only a fraction of that population exists today. The prospects of lake trout control and rehabilitating historical cutthroat trout abundance are yet to be achieved. Relatively low CPUE and an annual decrease in the size of sexually mature fish are indicators that the removal program is exerting pressure on this lake trout population. A continued focus on lake trout removal will be required into the future if cutthroat trout are to persist in Yellowstone Lake at a level allowing the overall integrity of the Greater Yellowstone Ecosystem to be maintained.

TODD KOEL

The National Park Service *Freedom* on Yellowstone Lake.

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Acknowledgements

Lake trout removal was enhanced through a three-year NPS Natural Resource Challenge, Natural Resource Preservation Program grant, and subsequent NPS base funding. Lynn Kaeding, Jeffrey Lutch, John McIntyre, S. Thomas Olliff, James Ruzycki, and James Selgeby were instrumental in the early development of the lake trout removal program. Cutthroat trout monitoring and lake trout removal would not occur without the dedicated assistance of many seasonal technicians and volunteers, and we are grateful for their support. Special thanks to Barbara Rowdon for her leadership on Yellowstone Lake, 2001–2004. Funding for whirling disease research has been provided by the National Partnership for the Management of Wild and Native Coldwater Fisheries, Montana Water Center, U.S. Fish and Wildlife Service, Whirling Disease Foundation, and NPS Rocky Mountain Ecosystem Studies Unit. Through collaboration with the Department of Ecology, Montana State University; U.S. Fish and Wildlife Service Bozeman Fish Health Laboratory; the U.S. Geological Survey Western Fisheries Research Center in Seattle; the Montana Department of Fish, Wildlife and Parks; and the Wyoming Game and Fish Department, we have been able to learn a great deal about whirling disease in the Yellowstone Lake ecosystem. Information on annual cutthroat trout spawning migration surveys and bear use of Yellowstone Lake tributaries was provided by Kerry Gunther of Yellowstone National Park's Bear Management Office and Daniel Reinhart, Patrick Perrotti, and Eric Reinertson of the park's Resource Management and Visitor Protection Division.

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Columbine Creek, a large spawning tributary on the eastern shore, disconected from Yellowstone Lake due to drought conditions in July 2004.

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